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PATENT

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Hirofumi HIGASHI	:
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SUBMISSION OF TRANSLATION

Assistant Commissioner of Patents
Washington, DC 20231

Sir:

Applicants submit herewith an English translation of International Patent Application No. PCT/JP2004/018829 including 15 pages and 3 sheets of drawing.

The attached document represents a true and complete English translation of International Patent Application No. PCT/JP2004/018829.

Respectfully submitted,

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DESCRIPTION

COMPRESSOR

TECHNICAL FIELD

[0001] The present invention relates to a compressor. In particular, it relates to measures against a loss of discharge pressure.

BACKGROUND ART

[0002] So far, compressors have been used in air conditioners and the like to compress a refrigerant in a refrigerant circuit. A known example of such compressors is a rotary compressor including a compressor mechanism and a motor for driving the compressor mechanism in a hermetic casing.

[0003] When the motor is driven, a piston revolves in a cylinder chamber of the compressor mechanism. According to the revolutions, a low pressure refrigerant is sucked into a suction chamber through a suction pipe, compressed to raise its pressure in a compressor chamber, and then discharged out to space in the casing through a discharge port.

[0004] The discharge port is generally provided with a flat reed valve. When the pressure in the compressor chamber exceeds a certain value, a distal end of the reed valve is warped to open the discharge port. After the refrigerant is discharged out of the compressor chamber to the space in the casing, the reed valve closes the discharge port by spring force of its own.

[0005] In the compressor mechanism as described above, however, reexpansion of the compressed refrigerant occurs to reduce the efficiency of the compressor (loss by reexpansion). Specifically, even after the discharge operation of the refrigerant, part of the refrigerant still remains in the volume of the discharge port, i.e., a dead volume. The remaining refrigerant reexpands in the compressor chamber to reduce volume efficiency.

[0006] To solve the above-described problem, for example, Japanese Unexamined

Patent Publication No. 2001-280254 proposes a compressor provided with a reed valve having a protruding part to be fitted in the discharge port, i.e., a so-called poppet valve. According to the compressor, the protruding part of the reed valve is fitted in the discharge port after the discharge is terminated, thereby reducing the dead volume. Therefore, the refrigerant remains less in the dead volume.

[0007] - Problem to solve -

When the reed valve of the compressor is lifted to the maximum level (full open state), the protruding part of the reed valve may possibly reduce the area of a flow passage formed in the discharge port. The reduced flow passage area causes flow resistance, thereby increasing a loss of discharge pressure. Further, when the reed valve is lifted to the maximum level, the refrigerant flows at high speed and the flow resistance is likely to increase. Thus, the reduction in flow passage area leads to a problem of increase in loss of discharge pressure.

[0008] The present invention has been achieved in view of the above-described problem. An object of the present invention is to reduce the loss of discharge pressure by forming a flow passage whose area is not reduced at any part of the discharge port at least when the reed valve is lifted to the maximum level to increase the flow rate.

DISCLOSURE OF THE INVENTION

[0009] The present invention solves the problem as described below.

[0010] Specifically, a compressor according to a first aspect of the present invention includes a reed valve **(41)** which opens and closes a discharge port **(29)** of a compressor mechanism **(20)** and includes a flat part **(41a)** and a protruding part **(41b)** formed at a distal end of the flat part **(41a)** to come in and out of the discharge port **(29)**, wherein the shape of the discharge port **(29)** and the shape of the reed valve **(41)** are determined to satisfy $S2 \geq S1 \geq S0$ wherein S0 is an opening area of an inlet **(29a)** of the discharge port **(29)**, S1 is the smallest sectional area of a flow passage formed between the protruding part **(41b)** and the discharge port **(29)** when the reed valve **(41)** is lifted to the maximum level and S2 is

the smallest sectional area of a flow passage formed between the flat part **(41a)** and the outer periphery of an outlet **(29b)** of the discharge port **(29)** when the reed valve **(41)** is lifted to the maximum level.

[0011] According to the first aspect of the present invention, as shown in FIG. **4**, the flow passage areas S0, S1 and S2 at different parts of the discharge port **(29)** satisfy $S2 \geq S1 \geq S0$ when the reed valve **(41)** is lifted to the maximum level. Therefore, the flow passage area is not reduced at any part of the discharge port **(29)**. Specifically, the amount of a compressed fluid flow will never be reduced during the period from when the fluid enters the discharge port **(29)** through the inlet **(29a)** to flow between the discharge port **(29)** and the protruding part **(41b)** until the fluid passes between the discharge port **(29)** and the flat part **(41a)**. Accordingly, flow resistance caused by reduction in flow passage area is less likely to occur and a loss of discharge pressure is reduced. In particular, as the above-described effect is achieved when the reed valve **(41)** is lifted to the maximum level, i.e., when the fluid flows at high speed and the flow resistance is likely to increase, the loss of discharge pressure is reduced with efficiency.

[0012] According to a second aspect of the present invention related to the first aspect of the present invention, the discharge port **(29)** is tapered from the outlet **(29b)** to the inlet **(29a)**.

[0013] According to the second aspect of the present invention, the flow passage area S1 of the discharge port **(29)**, i.e., the smallest sectional area of a flow passage formed between the discharge port **(29)** and the protruding part **(41b)**, increases with reliability. Accordingly, the flow passage area S1 surely becomes equal to or larger than the opening area S0 of the inlet **(29a)** of the discharge port **(29)**.

[0014] According to a third aspect of the present invention related to the first or second aspect of the present invention, a seat **(22b)** is formed at the outer periphery of the outlet **(29b)** of the discharge port **(29)** such that the seat **(22b)** contacts the flat part **(41a)**.

[0015] According to the third aspect of the present invention, the flat plate **(41a)**

contacts the outer periphery of the outlet **(29b)** of the discharge port **(29)** to seal the discharge port **(29)**. Accordingly, there is no need of adjusting the shape of the protruding part **(41b)** to the shape of the discharge port **(29)**, though it is required in the case where the discharge port **(29)** is sealed by contact between the protruding part **(41b)** and the inner surface of the discharge port **(29)**. Thus, the protruding part **(41b)** is made smaller than the discharge port **(29)** and the smallest sectional area S1 of the flow passage formed between the discharge port **(29)** and the protruding part **(41b)** increases with reliability.

[0016] - Effect -

According to the first aspect of the present invention, the shape of the discharge port **(29)** and the shape of the reed valve **(41)** are determined to satisfy $S2 \geq S1 \geq S0$ wherein S0 is an opening area of an inlet **(29a)** of the discharge port **(29)**, S1 is the smallest sectional area of a flow passage formed between the protruding part **(41b)** and the discharge port **(29)** when the reed valve **(41)** is lifted to the maximum level and S2 is the smallest sectional area of a flow passage formed between the flat part **(41a)** and the outer periphery of an outlet **(29b)** of the discharge port **(29)** when the reed valve **(41)** is lifted to the maximum level. Therefore, the amount of a fluid flow will never be reduced during the period from when the fluid enters the discharge port **(29)** through the inlet **(29a)** until the fluid passes between the discharge port **(29)** and the flat part **(41a)**. As the flow passage area is not reduced, flow resistance caused by reduction in flow passage area is prevented from occurring. Therefore, even during high speed operation when the fluid flows faster and is likely to receive greater flow resistance, the loss of discharge pressure is reduced with efficiency. As a result, the efficiency of the compressor improves.

[0017] According to the second aspect of the present invention, the discharge port **(29)** is tapered from the outlet **(29b)** to the inlet **(29a)**. Therefore, the smallest sectional area **S1** of the flow passage formed between the discharge port **(29)** and the protruding part **(41b)** when the reed valve **(41)** is lifted to the maximum level increases as compared with

the case where the discharge port **(29)** is cylindrical. Thus, the smallest sectional area **S1** is surely made equal to or larger than the flow passage area **S0** and the flow resistance caused by reduction in flow passage area is surely prevented from occurring.

[0018] According to the third aspect of the present invention, the seat **(22b)** is provided at the outer periphery of the outlet **(29b)** of the discharge port **(29)**. Accordingly, there is no need of adjusting the shape of the protruding part **(41b)** to the shape of the discharge port **(29)**, though it is required in the case where the discharge port **(29)** is sealed by contact between the protruding part **(41b)** and the inner surface of the discharge port **(29)**. Thus, the protruding part **(41b)** is made smaller than the discharge port **(29)**. Moreover, the flow passage area S1 is made larger to prevent the occurrence of the flow resistance caused by reduction in flow passage area.

BRIEF DESCRIPTION OF DRAWINGS

[0019] FIG. **1** is a sectional view illustrating a rotary compressor according to an embodiment.

FIG. **2** is a horizontal sectional view illustrating the rotary compressor according to the embodiment.

FIG. **3** is an enlarged sectional view illustrating the mechanism of a discharge valve system according to the embodiment.

FIG. **4** is a sectional view illustrating a reed valve of the embodiment which is lifted to the maximum level.

BEST MODE FOR CARRYING OUT THE INVENTION

[0020] Hereinafter, a detailed explanation of the embodiment of the present invention will be provided with reference to the drawings.

[0021] - Embodiment of the Invention -

A compressor of the present embodiment is a so-called rotary compressor **(1)** including a rotating piston as shown in FIGS. **1** and **2** (hereinafter simply referred to as a compressor). The compressor **(1)** includes a compressor mechanism **(20)** and a motor

(30) for driving the compressor mechanism (20) in a dome-shaped hermetic casing (10). The compressor (1) functions as a variable capacity compressor in which the motor (30) is controlled by an inverter to vary the capacity of the compressor stepwise or continuously. In the compressor (1), the compressor mechanism (20) is driven by the motor (30) to perform suction, compression and discharge of a refrigerant to circulate the refrigerant in a refrigerant circuit.

[0022] A suction pipe (14) and a discharge pipe (15) are provided at a lower part and an upper part of the casing (10), respectively.

[0023] The compressor mechanism (20) includes a cylinder (21), a front head (22), a rear head (23) and a piston (24). The front head (22) and the rear head (23) are fixed to the top end and the bottom end of the cylinder (21), respectively.

[0024] The cylinder (21) is a thick-walled cylindrical piece. A columnar cylinder chamber (25) is defined by the inner circumference surface of the cylinder (21), the bottom surface of the front head (22) and the top surface of the rear head (23). The cylinder chamber (25) is adapted to allow the piston (24) to revolve therein.

[0025] The motor (30) includes a stator (31) and a rotor (32). A drive shaft (33) is connected to the rotor (32). The drive shaft (33) passes through the center of the casing (10) and penetrates the cylinder chamber (25) in the vertical direction. The front head (22) and the rear head (23) are provided with bearings (22a and 23a) for supporting the drive shaft (33), respectively.

[0026] The drive shaft (33) includes a shaft body (33b) and an eccentric part (33a) situated in the cylinder chamber (25). The eccentric part (33a) has a larger diameter than that of the shaft body (33b) and its center is misaligned with the rotation center of the drive shaft (33) by a certain amount. The piston (24) of the compressor mechanism (20) is fitted around the eccentric part (33a). As shown in FIG. 2, the piston (24) is annular and configured such that its outer circumference surface contacts the inner circumference surface of the cylinder (21) substantially at a certain point.

[0027] The cylinder **(21)** is provided with a blade slit **(21a)** formed along the radius direction of the cylinder **(21)**. A blade **(26)** in the form of a rectangular plate is disposed in the blade slit **(21a)** to be slidable in the radius direction of the cylinder **(21)**. The blade **(26)** is biased inward in the radius direction by a spring **(27)** disposed in the blade slit **(21a)** such that its end is always in contact with the outer circumference surface of the piston **(24)**.

[0028] The blade **(26)** divides the cylinder chamber **(25)** formed between the inner circumference surface of the cylinder **(21)** and the outer circumference surface of the piston **(24)** into a suction chamber **(25a)** and a compression chamber **(25b)**. In the cylinder **(21)**, a suction port **(28)** is formed to penetrate the cylinder **(21)** in the radius direction from the outer circumference surface to the inner circumference surface such that a suction pipe **(14)** communicates with the suction chamber **(25a)**. Further, the front head **(22)** is provided with a discharge port **(29)** penetrating the front head in the axial direction of the drive shaft **(33)** to communicate the compression chamber **(25b)** with space in the casing **(10)**.

[0029] The front head **(22)** is provided with a discharge valve system **(40)** for opening and closing the discharge port **(29)**. The front head **(22)** is further equipped with a muffler **(44)** covering the top surface thereof.

[0030] As shown in FIG. **3**, the discharge valve system **(40)** includes a reed valve **(41)** and a valve guard **(42)**. The reed valve **(41)** is sandwiched between the valve guard **(42)** laid over the reed valve **(41)** and the front head **(22)**. The reed valve **(41)** and the valve guard **(42)** are fixed to the front head **(22)** at the proximal ends thereof by a fastening bolt **(43)**.

[0031] The discharge port **(29)** includes an inlet **(29a)** opened in the compression chamber **(25b)** and an outlet **(29b)** opened in the space in the casing **(10)**. The discharge port **(29)** is tapered from the outlet **(29b)** to the inlet **(29a)**.

[0032] The reed valve **(41)** includes a thin flat part **(41a)**. Further, a protruding part

(41b) protruding toward the discharge port **(29)** is formed at the distal end of the flat part **(41a)**. Specifically, the reed valve **(41)** is a so-called poppet valve. The protruding part **(41b)** is tapered toward the distal end thereof substantially in the same manner as the discharge port **(29)**. The reed valve **(41)** is configured such that the protruding part **(41b)** comes in and out of the discharge port **(29)** when the reed valve **(41)** is closed or opened. The outer periphery of the outlet **(29b)** of the discharge port **(29)** is protruded to function as a seat **(22b)** for receiving the flat part **(41a)** of the reed valve **(41)**. Specifically, when the pressure in the compression chamber **(25b)** is raised to a certain level, the flat part **(41a)** is warped along the curvature of the distal end of the valve guard **(42)** and the protruding part **(41b)** comes out of the discharge port **(29)**. Thus, the discharge port **(29)** is opened to discharge a high pressure gas refrigerant out to the space in the casing **(10)**. On the other hand, when the pressure in the compression chamber **(25b)** is reduced after the gas refrigerant has been discharged, the protruding part **(41b)** comes in the discharge port **(29)** under the spring force of the reed valve **(41)** and the flat part **(41a)** comes into contact with the seat **(22b)** to close the discharge port **(29)**. While the discharge port **(29)** is in a closed state, the protruding part **(41b)** occupies almost all the volume in the discharge port **(29)**.

[0033] As a characteristic feature of the present invention, the shape of the discharge port **(29)** and the shape of the reed valve **(41)** are determined such that flow passage areas S0, S1 and S2 at different parts of the discharge port **(29)** satisfy $S2 \geq S1 \geq S0$ when the reed valve **(41)** is lifted to the maximum level as shown in FIG. **4**, i.e., when the protruding part **(41b)** moves to the farthest position from the discharge port **(29)**. In FIG. **4**, the valve guard **(42)** and the fastening bolt **(43)** are omitted.

[0034] The flow passage area S0 is an opening area of the inlet **(29a)** of the discharge port **(29)**. The flow passage area S1 is the smallest sectional area of a flow passage formed between the discharge port **(29)** and the protruding part **(41b)**. The flow passage area S2 is the smallest sectional area of a flow passage formed between the seat **(22b)**

which is the outer periphery of the outlet **(29b)** of the discharge port **(29)** and the flat part **(41a)**. That is, the flow passage areas S0 to S2 are the smallest areas at the inlet, inside and outlet of the discharge port **(29)**, respectively.

[0035] The shapes of the discharge port **(29)** and the reed valve **(41)** are determined such that the flow passage areas S0, S1 and S2 become equal to each other or increase in this order. That is, their shapes are determined such that a flow passage formed in the discharge port **(29)** is not reduced at any part when the reed valve **(41)** is lifted to the maximum level. Therefore, when the amount of a fluid flow is maximized as the reed valve **(41)** is lifted to the maximum level, the amount of the fluid flowing from the compressor chamber **(25b)** will never be reduced during the period from when the fluid enters the discharge port **(29)** until the fluid is discharged out to the space in the casing **(10)**.

[0036] The discharge port **(29)** is tapered from the outlet **(29b)** to the inlet **(29a)**. Therefore, the flow passage area **S1**, i.e., the smallest sectional area of the flow passage formed between the discharge port **(29)** and the protruding part **(41b)** when the reed valve **(41)** is lifted to the maximum level, increases as compared with the case where the discharge port **(29)** is cylindrical. Thus, the flow passage area S1 surely becomes equal to or larger than the flow passage area S0.

[0037] As the seat **(22b)** is provided at the outer periphery of the outlet **(29b)** of the discharge port **(29)**, there is no need of adjusting the shape of the protruding part **(41b)** to the shape of the discharge port **(29)**, though it is required in the case where the discharge port **(29)** is sealed by contact between the protruding part **(41b)** and the inner surface of the discharge port **(29)**. Thus, the protruding part **(41b)** is made smaller than the discharge port **(29)**. By so doing, the smallest sectional area S1 of the flow passage formed between the discharge port **(29)** and the protruding part **(41b)** becomes large.

[0038] For example, the shapes of the discharge port **(29)** and the reed valve **(41)** are determined by adjusting the diameter øD of the inlet **(29a)** of the discharge port **(29)** and

the taper angle θ of the discharge port **(29)**. The maximum lift level H of the reed valve **(41)** may be adjusted as required to establish the above-described relationship among the flow passage areas S0 to S2.

[0039] - Operation -

Hereinafter, an explanation of how the above-described compressor is operated is provided below.

[0040] When the motor **(30)** is energized, the rotor **(32)** rotates. The rotations of the rotor **(32)** are transferred to the piston **(24)** of the compressor mechanism **(20)** via the drive shaft **(33)**. In this way, the compressor mechanism **(20)** performs the compression as required.

[0041] The compression performed by the compressor mechanism **(20)** is explained more specifically with reference to FIG.2. When the piston **(24)** is driven by the motor **(30)** to revolve to the right (clockwise), the capacity of the suction chamber **(25a)** increases as the piston revolves and a low pressure refrigerant is sucked into the suction chamber **(25a)** via the suction port **(28)**. The suction of the refrigerant into the suction chamber **(25a)** is continued until the piston **(24)** revolving in the cylinder chamber **(25)** comes to the immediate right of the suction port **(28)** to contact the cylinder **(21)**.

[0042] When the piston **(24)** makes a single revolution as described above and the suction of the refrigerant is terminated, the compression chamber **(25b)** for compressing the refrigerant is provided. Next to the compression chamber **(25b)**, a new suction chamber **(25a)** is formed and the suction of the refrigerant therein is performed repeatedly. As the piston **(24)** revolves, the capacity of the compression chamber **(25b)** decreases to compress the refrigerant in the compression chamber **(25b)**. When the pressure in the compression chamber **(25)** is raised to a certain level, the protruding part **(41b)** of the reed valve **(41)** comes out of the discharge port **(29)** to open the discharge port **(29)**. The refrigerant in the compression chamber **(25b)** enters the discharge port **(29)** through the inlet **(29a)**, flows between the discharge port **(29)** and the protruding part **(41b)**, and then

passes between the seat **(22b)** and the flat part **(41a)** to go out to the space in the casing **(10)**. After the high pressure refrigerant is discharged and the pressure in the compression chamber **(25b)** is reduced, the protruding part **(41b)** of the reed valve **(41)** comes in the discharge port **(29)** by its own rigidity (spring force) and the flat part **(41a)** comes into contact with the seat **(22b)** to close the discharge port **(29)**. In this way, the suction, compression and discharge of the refrigerant is performed repeatedly.

[0043] During high speed operation, the amount of discharged gas increases and the reed valve **(41)** is lifted to the maximum level (warped at the maximum). The amount of a refrigerant flow from the compression chamber **(25b)** will never be reduced during the period from when the refrigerant enters the discharge port **(29)** through the inlet **(29a)** until the refrigerant passes between the seat **(22b)** and the flat plate **(41a)**. Therefore, even during high speed operation where the refrigerant flows faster and is likely to receive greater flow resistance, the flow resistance caused by reduction in flow passage area is prevented from occurring. Thus, the loss of discharge pressure is reduced with efficiency.

[0044] - Effect of the Embodiment -

As described above, according to the present embodiment, the shapes of the discharge port **(29)** and the reed valve **(41)** are determined to satisfy $S2 \geq S1 \geq S0$, wherein $S0$ is the opening area of the inlet **(29a)** of the discharge port **(29)**, $S1$ is the smallest sectional area of the flow passage formed between the protruding part **(41b)** and the discharge port **(29)** when the reed valve **(41)** is lifted to the maximum level and $S2$ is the smallest area of the flow passage formed between the flat plate **(41a)** and the seat **(22b)** when the reed valve **(41)** is lifted to the maximum level. Accordingly, the amount of the refrigerant flow from the compression chamber **(25b)** will never be reduced during the period from when the refrigerant enters the discharge port **(29)** through the inlet **(29a)** until the refrigerant passes between the seat **(22b)** and the flat plate **(41a)**. Therefore, even during high speed operation where the refrigerant flows faster and is likely to receive greater flow resistance, the flow resistance caused by reduction in flow passage area is

prevented from occurring. Thus, the loss of discharge pressure is reduced with efficiency.

[0045] As the discharge port **(29)** is tapered from the outlet **(29b)** to the inlet **(29a)**, the flow passage area **S1**, i.e., the smallest sectional area of the flow passage formed between the discharge port **(29)** and the protruding part **(41b)** when the reed valve **(41)** is lifted to the maximum level, increases as compared with the case where the discharge port is cylindrical. Thus, the flow passage area **S1** surely becomes equal to or larger than the flow passage area **S0** and the flow resistance caused by reduction in flow passage area is prevented from occurring with reliability.

[0046] Further, as the seat **(22b)** is provided at the outer periphery of the outlet **(29b)** of the discharge port **(29)** to contact the flat part **(41a)**, there is no need of adjusting the shape of the protruding part **(41b)** to the shape of the discharge port **(29)**, though it is required in the case where the discharge port **(29)** is sealed by contact between the inner circumference surface of the discharge port **(29)** and the protruding part **(41b)**. Therefore, the size of the protruding part **(41b)** is made smaller than that of the discharge port **(29)**. By so doing, the above-described smallest sectional area **S1** becomes large.

[0047] - Other Embodiments -

The above-described embodiment of the present invention may be modified as described below.

[0048] The above-described embodiment is directed to the rotary compressor **(1)** including the piston. However, the present invention may be applied to swing piston compressors and scroll compressors. That is, the present invention may be applicable to any compressor as long as a so-called poppet valve **(41)** is provided at the discharge port **(29)** of the compression chamber **(25b)** as a working chamber.

[0049] In the above-described embodiment, the discharge port **(29)** is tapered. However, the discharge port **(29)** of the present invention may be cylindrical.

[0050] Further, in the above-described embodiment, the seat **(22b)** for the reed valve **(41)** is provided at the outer periphery of the outlet **(29b)** of the discharge port **(29)**.

However, the seat may be formed at the inner surface of the discharge port **(29)** such that it contacts the protruding part **(41)** to seal the discharge port **(29)**.

INDUSTRIAL APPLICABILITY

[0051] As described above, the present invention is useful as a compressor for compressing various kinds of fluid.